LTE/LTE-Advanced Overview
Course Number: LTE4000-01EN | Duration: 2 Days

Target Audience
• UE & E-UTRAN Development Staff
• Network Engineering & Optimisation Personnel
• System Design Engineering Staff, IOT & System Test Engineers
• Technical Sales and Marketing Personnel

Prerequisites
• None

Learning Objectives
After completing this course, the students will be able to:
• Understand LTE key features and able to identify the major steps in the network architecture evolution towards an LTE network.
• Know the LTE network architecture, interfaces and protocols stacks.
• Describe OFDM, OFDMA, SC-FDMA concepts.
• Describe LTE air interface channel types and its characteristics.
• Know UE states and main signaling procedures.
• Explain different LTE voice services.
• Give example of LTE deployment scenario.

Course Outline
1. Introduction and Background
   1.1 Motivation and Major Steps in Network Architecture Evolution towards LTE
   1.2 Standardisation Bodies around LTE
   1.3 LTE Key Features
   1.4 LTE-Advanced Main Features
2. LTE Network Architecture and Protocols
   2.1 LTE/SAE Network Subsystem
   2.2 LTE/SAE Network Elements and its Functions
   2.3 Protocol Stacks and Network Interfaces
   2.4 LTE Roaming Architecture
   2.5 LTE Interworking Architecture with 2G/3G/Non-3GPP Networks
3. LTE Air Interface
   3.1 Multiple Access Concepts
   3.2 Basic of OFDM, OFDMA, OFDMA Signal Generation Concepts
   3.3 Basic of SC-FDMA, SC-FDMA Signal Generations Concepts
   3.4 LTE Subcarriers, Frame Structure, Resource Block and Modulation Options
   3.5 LTE Channel Structure
   3.6 LTE Channel Characteristics
   3.7 Basic of Multiple Antenna Technologies
   3.8 LTE Max. Bit Rate Calculation
   3.9 LTE UE Capabilities
4. UE States and Signaling Procedures
   4.1 UE States (ECM, EMM and ESM)
   4.2 Synchronisation and Cell Search
   4.3 Random Access
   4.4 RRC Connection Establishment
   4.5 Attach and Default Bearer Establishment
   4.6 Dedicated Bearer Establishment
   4.7 Tracking Area Update
   4.8 Intra-System Handover
   4.9 LTE Authentication Procedures
5. LTE Voice Services
   5.1 CSFB
   5.2 VoIP, Protocol Stack, ROHC
   5.3 VoLGA
   5.4 SRVCC
   5.5 TTI Bundling
   5.6 Semi-Persistent Scheduling
6. LTE Deployments
   6.1 Example of LTE Deployment Scenarios
   6.2 Radio Frequency Aspects
   6.3 FDD vs. TDD Aspects

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Target Audience
- System Design & Customer Support Personnel
- UE/E-UTRAN SW Developers and IOT/System Test Engineers
- Network Engineering & Performance Optimisation Staff

Prerequisites
- LTE/LTE-Advanced Overview (LTE4000-01EN)

Learning Objectives
After completing this course, the students will be able to:
- Know about different LTE releases (Rel. 8, 9, 10, 11) and the major feature additions in each release.
- State UE’s optional and mandatory radio access capability parameters and features not tested.
- Understand how Carrier Aggregation operates with different CA Bandwidth Classes.
- Explain E-UTRA transmission modes and suitable antennas to enhance peak and/or cell edge performance.
- Describe LTE’s HARQ operation in conjunction with eNodeB’s link adaptation to maintain BLER target.

Course Outline
1. Evolved Packet System Network Layout
   1.1 E-UTRAN & Evolved Packet Core
   1.2 LTE-Uu Characteristics
   1.3 NAS & Access Stratum Identifiers
   1.4 Basics about Network Access (Signaling)
   1.5 HetNet and Relays
   1.6 HeNB
   1.7 CoMP
2. LTE Air Interface Design
   2.1 OFDMA & SC-FDMA
   2.2 LTE Bands & flexible Bandwidth Support
   2.3 Frame & Subframe Structure
   2.4 E-UTRA Transmission Modes & Antennas
   2.5 Channel & Bearer Concept
   2.6 Layer 1 Processing Steps
3. LTE Resource Allocation
   3.1 Resource Element & REG’s vs. PRB
   3.2 Physical Channels & RE/RB Mapping
   3.3 Physical Signals & RE Mapping
   3.4 Dynamic Resource Block Assignment
   3.5 Uplink PUCCH Resource Assignment
   3.6 CQI Transmission
   3.7 Ack/Nack Transmission (DL/UL)
   3.8 Carrier Aggregation
4. Hybrid ARQ & Link Adaptation
   4.1 Convolutional & Turbo Coding
   4.2 Retransmission Combining
   4.3 MCS Selection & Link Adaptation
   4.4 Open Loop vs. Closed Loop HARQ
   4.5 HARQ Failure & Block Segmentation
5. MIMO
   5.1 Transmission Modes
   5.2 SU-MIMO
   5.3 MU-MIMO
6. Physical Layer Procedures
   6.1 LTE Cell Search
   6.2 RSRP & RSRQ Measurements
   6.3 System Information Decoding
   6.4 Random Access Procedure
   6.5 Paging Cycle & Monitoring
   6.6 Uplink Power Control (PUSCH/PUCCH)
   6.7 Sounding
7. RLC/MAC Operation
   7.1 PDCCH Order
   7.2 Timing Advance Update
   7.3 Scheduler Functionality
   7.4 Higher Layer SDU Processing
   7.5 RLC Status & L2 Retransmissions
8. PDCP Functionality
   8.1 Integrity Protection & Ciphering
   8.2 Robust Header Compression
   8.3 Lossless Handover
9. RRC Operation
   9.1 RRC Establishment Procedure
   9.2 RRC Re-establishment
   9.3 SRB & DRB Reconfiguration
   9.4 Measurement Control & Reporting
   9.5 LTE Mobility – Handover & Redirect
   9.6 Inter RAT Mobility
10. EMM & ESM Operation
    10.1 UE Voice Domain Preference & Usage
    10.2 LTE Attach & Default EPS Bearer
    10.3 Reasons for Tracking Area Update
    10.4 Dedicated EPS Bearer Activation
    10.5 IMS Discovery & Registration
    10.6 VoLTE & SRVCC Signaling
LTE/LTE-Advanced Signaling & Protocols
on Uu Interface
Course Number: LTE4300-01EN | Duration: 4 Days

Target Audience
• UE/E-UTRAN SW Developers and IOT/System Test Engineers
• Network Engineering & Performance Optimisation Staff

Prerequisites
• LTE/LTE-Advanced Air Interface (LTE4200-01EN)

Learning Objectives
After completing this course, the students will be able to:
• Understand how EMM and ESM failure affect the UE’s protocol behavior.
• Describe UE’s tasks in priority based intra LTE and Inter-RAT cell reselection.
• Get behind the drawbacks and advantages of CSFB versus VoLTE with SRVCC.
• Explain E-UTRAN measurement events, reasons for handovers & RRC re-establishments.
• Set user plane & control plane parameters to reduce drops related to RLC, RRC & layer1.

Course Outline
1. UE’s Idle Mode Procedures
   1.1 PLMN/Cell Search and Selection
   1.2 Priority based LTE Cell Reselection
   1.3 IRAT Priority based Cell Reselection
2. Physical Layer Procedures
   2.1 Random Access & PDCCH Order
   2.2 HARQ – Open & Closed Loop
   2.3 Layer 1 UL & DL Resource Allocation
   2.4 SU-MIMO/Spatial Multiplexing (DCI’s)
   2.5 Beamforming & MU-MIMO (DCI’s)
   2.6 Paging & System Info Transmission
   2.7 Semi Persistent Scheduling
3. RRC Connected Mode Signaling Procedures
   3.1 RRC Connection Re-/Establishment
   3.2 SRB & Radio Bearer Configurations
   3.3 RRC Measurement Controls
   3.4 Handover Signaling – RRC & Layer 1
   3.5 ANR and CGI Reporting for 4G/3G/2G
   3.6 DRX Configuration & Activation
4. LTE NAS & Application Layer Procedures
   4.1 EMM Attach & SGs-Discovery
   4.2 EMM Combined Attach & Tracking Area
   4.3 ESM Default EPS Bearer (IPv4v6)
   4.4 ESM Dedicated EPS Bearer Setup
   4.5 SIP De-/Registration Procedures
   4.6 VoLTE Bearer Configuration
   4.7 SRVCC from LTE to 2G/3G (CS Only and CS+PS Related Bearers)
5. Inter RAT Changes and Handover
   5.1 4G ↔ 3G Handover (CS/PS)
   5.2 Redirections for CSFB and PS
   5.3 Redirections with SI and DMCR
   5.4 NACC & CCO (4G ↔ 2G)
6. MAC Functions & Operation
   6.1 Transfer of higher Layer SDU’s
   6.2 MAC Control Elements
   6.3 BSR & PHR Reporting
   6.4 Prioritised Bit Rate (PBR)
7. RLC Procedures & Functionality
   7.1 RLC-SDU Transfer between Peers
   7.2 RLC & MAC Interworking
   7.3 RLC Status & Retransmissions
   7.4 SDU Segmentation & Reassembly
   7.5 RLC-Counter, Timer & Max. Retransmission
8. PDCP Functions & Operation
   8.1 PDCP Headers – Control & User Plane
   8.2 ROHC for TCP/IP & RTP/UDP/IP
   8.3 Lossless Handover
   8.4 Ciphering & Integrity Protection
   9.1 Min. Overhead of MAC/RLC/PDCP
   9.2 Max. Possible Throughput per UE Cat
   9.3 Handover Delay’s & SDU Stalling

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LTE/LTE-Advanced Radio Planning
Course Number: LTE4400-01EN | Duration: 3 Days

Target Audience
- Network Planning/Performance Engineering Staff
- System Test/IOT Test Engineers and Optimisation Personnel

Prerequisites
- LTE/LTE-Advanced Overview (LTE4000-01EN) and LTE/LTE-Advanced Air Interface (LTE4200) or Equivalent Knowledge

Learning Objectives
After completing this course, the students will be able to:
- Name the fundamental approach to design the LTE radio network.
- Evaluate radio propagation and related phenomena.
- Understand the concept of coverage analysis by means of link budget and planning tools.
- Analyse capacity and dimensioning related aspects.
- State initial parameter tuning steps.
- Recall inter-frequency and inter-RAT related topics.
- Understand specific aspects of indoor and in-house deployment.

Course Outline
1. Introduction
   1.1 Generic Network Design
   1.2 Greenfield Approach
   1.3 Re-use of Existing Grids
2. Radio Propagation
   2.1 Fundamentals
   2.2 Pathloss Models
   2.3 Antenna Aspects
   2.4 Fading and Shadowing
   2.5 Indoor
3. Coverage Analysis
   3.1 UL/DL Link Budget and MAPL
   3.2 Cell Range Estimation
   3.3 Tool-supported Coverage Planning
4. Capacity Analysis
   4.1 Peak Data Rate vs. Practical T-Put
   4.2 Spectral Efficiency
   4.3 Capacity Estimation by Means of SINR, CQI, MCS
   4.4 Multi Antenna Deployment
   4.5 Capacity Enhancing Features
   4.6 Simulation Tools
5. Traffic Modeling
   5.1 QoS-Aspects
   5.2 Time Variations
   5.3 Spatial Distribution
   5.4 Traffic Simulation
   5.5 Traffic Forecasting
6. Dimensioning
   6.1 Coverage Requirements
   6.2 Capacity Based Approach
   6.3 Verification and Related KPI
7. Initial Parameter Settings
   7.1 PCI
   7.2 DMRS
   7.3 PRACH/RACH
   7.4 PUCCH
8. Inter-Frequency and Inter-RAT
   8.1 RF Considerations
   8.2 Load Aspects
   8.3 Idle Mode Mobility
   8.4 Connected Mode Mobility
9. Indoor/In-house Planning
   9.1 Indoor Propagation Models
   9.2 Additional Losses
   9.3 Coverage Calculation
   9.4 Capacity Estimation
   9.5 In-house Deployments

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„Vorsprung durch Spezialisierung“
LTE/LTE-Advanced Parameter Optimisation & Troubleshooting on Uu Interface
Course Number: LTE4500-01EN | Duration: 5 Days

Target Audience
• Network Planning/ Performance and KPI Engineering Staff
• Network Optimisation Personnel and System Test / IOT Engineers

Prerequisites
• LTE/LTE-Advanced Signaling & Protocols on Uu Interface (LTE4300-01EN)

Learning Objectives
After completing this course, the students will be able to:
• Evaluate drive-tests logs and critical signaling faults as well as procedure mistakes.
• Analyse RRC parameter settings and their performance impact on LTE-Uu.
• Optimise HO procedures and their related parameters to reach better network performance.
• Debug critical system problems in UE & E-UTRAN as well as interworking with Core and IRAT.
• Improve E2E network KPI’s and Subscriber’s quality of experience (QoE).

Course Outline
1. System Acquisition and Network Access
   1.1 Overview of E-UTRAN & EPC
   1.2 SIB Transmission & Parameterisation
   1.3 Paging & Tracking Area Capacity
2. Physical Channel Planning & Optimisation
   2.1 PCI Planning Guideline
   2.2 DM-RS Planning Rules
   2.3 PRACH Parameter Optimisation
   2.4 PUCCH Parameter Analysis
   2.5 PDCCH Configuration & Performance
   2.6 HARQ & RLC Parameterisation
3. RRC Connection and Bearer Optimisation
   3.1 RRC Connection Setup Parameter
   3.2 Default EPS Bearer & DRB Parameter (BSR & PHR Optimisation)
   3.3 Short & Long DRX Configuration and Impact on Battery Life
   3.4 Dedicated Bearer Parameter (SPS Parameterisation)
4. Idle Mode Mobility in Rel. 8 – Rel. 10
   4.1 Measurement Types
   4.2 Cell (Re-)Selection & Priority with RFSP
   4.3 Inter RAT (Priority) Reselection & Redirection – inherited Priorities
5. Connected Mode Mobility
   5.1 HO Events and Trigger Parameters
   5.2 Intra-LTE HO Parameter Analysis
   5.3 Inter-RAT HO Parameter Analysis
   5.4 CSFB Procedure Problems & Delays
   5.5 SRVCC HO for CS and PS – Cipher Issue
   5.6 ANR Performance for CGI Reading (HeNB/CSG’s)
6. Power Control and Power Setting
   6.1 UL Power Control for Cell Edge UE’s
   6.2 Open vs. Closed Loop Performance
   6.3 SRS – Timing Advance & Power Control
   6.4 DL Power Boosting for 64QAM
7. NAS Problems & their Root Cause Analysis
   7.1 Attach Accept Fail for CS & Rejects
   7.2 TAU Reject Causes and Reasons
   7.3 Reasons for PDN Connectivity Rejects
   7.4 Service & Extended Service Rejects
   7.5 Procedure Collisions
   (CSFB & QoS Modifications)
   7.6 MOCN & EPLMN Issues
8. Radio Performance Optimisation
   8.1 ICIC & eICIC
   8.2 Connection Drop Analysis – 7 Reasons
   8.3 Frequency Domain Packet Scheduler
   (Performance Improvements)
   8.4 Load-based SINR Deterioration
   8.5 MIMO Condition Number vs. RI & CQI
9. Throughput vs. Capacity Optimisation
   9.1 Three Ways to throttle UE’s Throughput (QoS, eNB, Backhaul)
   9.2 TCP Parameterisation (WS vs. RTT)
   9.3 S1-Backhaul Issues & Clock Stability
10. SON – Self Organising Networks
    10.1 Review of SON Features from Rel.8
    10.2 Self Optimising Features from Rel. 9
    10.3 Minimisation of Drivetests (MDT)
    10.4 Geotracing/Tracking